THURSDAY, JANUARY 14, 1875

THE APPROACHING ECLIPSE OF THE SUN

THE energetic action of the Council of the Royal Society, and the wise liberality of the present Government in matters connected with scientific investigation, have saved us from what would have been little short of a national disgrace.

If all goes well, the approaching eclipse of the Sun – during which, as stated by Mr. Hind, better opportunities for the observation of totality will be afforded than are likely to be again offered before the close of the present century—will be observed by English parties in Siam, and either in Burmah or in some island in the Bay of Bengal.

The work to be done, as determined by the Council of the Royal Society, and the investigations which have led up to it and render it of so great an importance, have been stated in Monday's *Times* in an article which enters so fully into the problem, that we take the following extracts from it :—

"In 1860, Mr. De la Rue, a member of the Astronomer Royal's Expedition, and Father Secchi, a delegate of the Italian Government, were enabled, by the photographs of the eclipsed Sun, which were then taken for the first time, to place beyond all doubt that the strange red prominences seen round the dark body of the Moon at the moment of total eclipse really belonged to the Sun's atmosphere. This was a fine achievement, for it settled a point which had been in debate for a century and a half. Important though it was, however, it was fairly dwarfed by the results of the expeditions sent by the Indian, French, German, and Austrian Governments to observe the eclipse of 1868 in India—dwarfed because in the meantime an instrument had been placed in the hands of the astronomer of a perfectly new kind of power. It was no longer a question of place and shape, but of material. Janssen, Tennant, Pogson, Weiss, and many others observed the eclipse with the spectroscope, and its story was that the prominences which in 1860 had been proved to belong to the Sun really consisted of a glowing gas, or a mixture of such gases. But the spectroscope was not of use only during eclipses. Before 1868 Kirchhoff by its means had stated the approximate composition of the Sun's atmosphere, taken as a whole ; and immediately after the eclipse of that year it was found that by its aid the brightest part of the Sun's atmosphere, to which alone up to this time attention had been directed, could be seen without an eclipse at all. Indeed, we were soon told that outside the bright round disc that we see there was an evelope of glowing hydrogen gas, to which envelope the name of chromosphere was given, and into which are frequently injected from below magnesium and sodium, and, more rarely, iron and the other heavy metals. Here, then, we were enabled roughly to sort out into strata the various substances already detected by Kirchhoff ; that is, it was established that the gases and vapours were not all mixed up together, but that the lightest, such as hydrogen, magnesium, and sodium, were generally at top, and that, as the others were shot up from time to time, and some of them more frequently than others, some of them were, as a rule, located lower down in the solar atmosphere than the others.

"The eclipse of 1869 the Americans had all to themselves, and splendid use they made of it. It has been well said that the line of totality which swept across the United States was one continuous observatory. In this eclipse the halo of light outside the prominence-envelope was the subject of special inquiry, and now this was photographed, as the prominences themselves had been in 1860. At the same time that this was done it was established that there was some other substance lying even outside the hydrogen.

"The eclipse of the next year, 1870, was best seen in different parts of the Mediterranean. The English Government, applied to by the Royal and Astronomical Societies, at once supplied the requisite funds and ships, and sent three parties ; the United States Government sent an equal number ; and the French one party, the Spanish and Italian astronomers observing locally. Further facts were obtained of great value ; but the weather was not good, and the true nature of the corona was not considered to be finally established. Another appeal was therefore made to the Government in 1871 by the Presidents of the British Association, the Royal Society, and the Astronomical Society combined, to observe the eclipse of that year in India. The Government responded with a remarkable promptitude, granting everything that was required. The Indian Government not only had strong parties of their own, but largely aided the observers sent out from England ; and the French Government were again represented by the illustrious Janssen, who had made his exit from beleaguered Paris in a balloon to observe the phenomenon. The Dutch Government had an expedition in Java. The combination of the results of the parties, most of whom had splendid weather, led to the following most important conclusions :—

"First, the corona was now at last photographed, under nearly the same instrumental conditions, from three different places, and the exact similarity of the pictures proved beyond all doubt that part of the corona was a solar appendage. The size of the Sun was enormously increased by this result. Secondly, evidence was obtained rendering it extremely probable that the light of the outer parts of the true solar corona, or *coronal atmosphere*, as Janssen proposed to call it, was stronger in the violet and ultra-violet parts of the spectrum than elsewhere. Thirdly, it was proved that for some distance above the hydrogen envelope, as seen without an eclipse, less bright hydrogen existed. The so-called chromosphere, therefore, was a layer of brighter hydrogen and other vapours. Other results were obtained, but the above are those on which we wish to lay the greatest stress, for reasons we now proceed to state.

"Since the eclipse of 1871 the every-day observations of the Sun and of his lower atmosphere (the chromosphere), which can be rendered visible by the spectroscope, have gone on with great vigour, especially in Italy. A special study of the chromosphere has been made at the expense of the United States Government, at an elevation of some 9,000 feet, on the Rocky Mountains ; and extensive laboratory researches have been undertaken with the view of enabling us to understand better the various phenomena observed. We shall now only refer to the two latter branches of the work. Prof. Young, on the Rocky Mountains, in the clear air at so great a height, saw that the chromosphere was much more complicated than it appears to those who observe in the plains. Among other things, he found that the vapour of the metal calcium, the principal characteristic lines of which require perfect atmospheric conditions to enable us to see them, was very often present along with magnesium, but his observation left it doubtful which vapour extended highest generally. The laboratory experiments proved that, in the case of any one metal present in the Sun, the metal behaves exactly the same in the Sun's atmosphere as it does when driven into vapour by the passage of the electric current between the carbon poles of an electric lamp. At the greatest distance from the poles the spec-

trum of the vapour is the simplest (single-lined), in the core of the arc it is complex (many-lined). Now, in the case of some of the elements present in the Sun, we have a spectrum as complete as that we get in the core of the arc, in others only a line or two, so far as we know at present. In fact, we have hydrogen and the metals of the alkalis and alkaline earths and the metals of the iron class with almost complete spectra on the one hand, and on the other only a few lines indicating the presence of such metals as zinc and lead.

"Nor is this all. A most diligent search has been made for metals of the tungsten, antimony, silver, and gold classes among the metals, and entirely without success. Dealing, however, with the metals the record of which is most obvious in the solar spectrum, hydrogen, magnesium, calcium, sodium, and the metals of the iron group, the order we have given is not only the order in which they would be met by a body entering into the solar atmosphere, but it is the order of the old atomic weights. Further, although it is true that at present we do not know much about the spectra of the stars, we do know that the stars with the simplest spectra are stars which only give clear indications of hydrogen, or hydrogen and magnesium, or hydrogen, magnesium, sodium, and so on. A star as it gets gradually older may apparently give us a spectrum belonging to a gradually increasing depth of the solar atmosphere as it exists at this moment.

"So far we have said nothing about metalloids; that is, those elementary bodies, such as oxygen, carbon, nitrogen, sulphur, and the like, which make up more than half of the parts of our planet most easily got at. Of metalloids in the chromosphere none have been detected, but a year ago a paper was presented to the Royal Society pointing out that their record would appear not to be entirely absent from the solar spectrum; in fact, that we have exactly such a record as we should expect if this large class of bodies existed in a comparatively cool part of the atmosphere at some height above the hotter lower strata. It was also shown that, granting this, we could explain the various classes of stars in the heavens by supposing that as a star got older and colder the metalloids were enabled to exist lower down in the atmosphere, and thus to change the character of the spectra of stars bright and hot into that associated with those which are dim and possibly colder, until at last the metalloidal rain, so to speak, falling on the metals below, gives the material of a future crust. It will be seen, then, that the work since 1871 has been assuming more and more a chemical character, and associated with this are physical questions of the greatest interest, not only bearing on the kinetic theory of gases, but which may eventually help us to follow more intelligently than we can now the matter of a nebula till it forms part of the cooled crust of a planet.

"The present line of inquiry, then, is to determine the chemical nature of a section of the Sun's atmosphere reaching from the photosphere to the extreme limit of the corona, some hundreds of thousands of miles away. This with the old conditions of observation, would have been a hopeless task to accomplish. But, side by side with the results to which we have drawn attention, new methods of investigation have been introduced, and among these the development of spectrum photography deserves first mention. The spectrum of the corona can now be photographed with the same ease as the prominences were photographed in 1860, and if such photographs can be obtained, it is certain that the work of four minutes will in all probability be more valuable than laboratory work extending over as many years. But even spectrum photography would not have been applicable under the best conditions unless side by side with it an instrument had been introduced which is destined to effect a great revolution in astronomical observation. In the Siderostat we have an instrument, suggested by Hooke and perfected by Foucault, which enables us to do away with telescope stands and their equatorial mountings altogether. This is effected by moving a large, perfectly plain mirror in front of the object glass of a telescope, the telescope itself being horizontal and at rest. This arrangement permits of spectroscopes and photographic apparatus being attached to the eye-piece end of the telescope of even greater dimensions than the telescope itself. The special and novel method of attack to which Mr. De la Rue referred as having been suggested to the Council of the Royal Society can now be guessed by our readers; and unless we have missed the mark altogether, it should now be seen that the work of the proposed expedition of this year is the fruit and crown of the work begun in 1860 and carried on by the English and other civilised Governments since that time. . . . ."

We have little to add to the foregoing, except that it appears to us a sad thing, and little to the credit of the leaders of astronomy in England, that such strong arguments should have to be put forward at all in favour of eclipse observations. *Every total eclipse of the Sun ought to be observed as a piece of the national business with as great a regularity as the transit of the Moon over the meridian of Greenwich.* Nay, we may go further, and say with *greater* regularity; for we know something about the motion of the Moon, and we can predict her place with some accuracy, but he would be a bold man who would predict the shape and condition of the Sun's surroundings in the forthcoming eclipse. Practical men might possibly urge the greater utility of one kind of observation, but a man of science who does this is to our mind not a true man of science at all.

Mr. Hind has sent us the following most valuable information regarding the actual conditions of observation, referring at somewhat greater length to Siam, whither English astronomers are invited by the King of Siam.

"Although the course of the central line in this eclipse is mainly a sea-track, yet in its passage from the Nicobar Islands, in the Bay of Bengal, to Siam, better opportunities for the observation of totality will be afforded than are likely to be again offered before the close of the present century.

"Adopting the elements of the *Nautical Almanac*, in which the place and hourly motions of the moon are derived from Hansen's Tables, I find the following points upon the central line:—

Greenwich Mean Time.	Longitude East.	Latitude North.	Sun's Altitude.
H. M. S.	° ′	° ′	° ′
19 8 0	92 36·9	7 34·2	71 8
19 14 0	94 20·2	9 1·6	67 51
19 23 0	97 9·5	11 10·4	62 38
19 26 0	98 9·9	11 52·7	60 51
19 28 30	99 2·5	12 27·3	59 18
19 32 0	100 19·7	13 15·9	57 6

"If we lay down these points on the Admiralty Charts of the Bay of Bengal and Province of Tenasserim (British Burmah), we find the central line passing a little north of Kaikul, in the Island of Camorta, Nicobars, and on making a direct calculation for Kaikul, totality is found to commence at 1h. 21m. 38s. local mean time, and to continue 4m. 27s., the sun being at an altitude of about 70°. I take the position of Kaikul, 6h. 13m. 31s. E. and 8° 11′·8 N. The central eclipse, passing from the Nicobars, traverses Bentinck Island, where the maximum duration of totality is 4m. 17s., and runs between Mergui and Tenasserim, rather nearer to the former place than to the latter. By direct calculations I find—

Totality begins at Mergui at . . . . 2h. om. 6s. local time.

Duration	...	...	4m. 6s.
Sun's altitude	...	...	61°

Totality begins at Tenasserim at 2h. 2m. 7s. local time.

Duration	...	...	3m. 57s.
Sun's altitude	...	...	60°

Nearly midway between the above places, or where a "Conical Peak" is marked on the Admiralty Chart, the total eclipse continues 4m. 14s.

"Bangkok (Siam) will be found to lie rather north of the central line. The circumstances of the eclipse at this point are as follows (long. 6h. 42m. 6s. E.; lat 13° 42′ 5″ N.)

"The partial eclipse begins at oh. 51m. 6s. mean time at Bangkok, 134° from the north point towards the west, and 168° from the vertex eastward, for *direct* image; the sun at an altitude of 76°. The total eclipse begins at 2h. 13m. 7s. and continues 3m. 54s., the sun about 57° high, and the partial phase ends at 3h. 33m.

"The invitation extended to British and other astronomers by the King of Siam, to observe this interesting and important phenomenon within his dominions, may be expected to bring together a number of competent observers in the vicinity of Bangkok; and in selecting localities for astronomical stations, it must be very desirable to be enabled to form some idea of the extent of error to which the predicted track of the central line may be subject. On this account I have made a further direct calculation for the Siamese capital, taking the moon's position from the American Ephemeris, in which the Tables of Prof. Peirce are employed. With elements thus modified, the partial phase is found to commence at oh. 50m. 42s., or 24 seconds only earlier than by Hansen's Tables; totality begins at 2h. 13m. 32s., and continues 3m. 59s. Generally I may remark that between the longitudes of the Nicobars and Siam, the track of central line by the American Tables has about five minutes greater latitude than that given by Hansen's Tables.

"(For any point in Siam in the neighbourhood of Bangkok, the *Greenwich* time of commencement of the partial eclipse will be given closely by the following formula:—

$$\text{Cos. } w = -0{\cdot}08471 - [0{\cdot}12053] \sin. l + [0{\cdot}12430] \cos. l, \cos (L - 172^\circ\ 10''{\cdot}1)$$
$$t = 18\text{h. } 55\text{m. } 58\text{s.} - [3{\cdot}71146] \sin. w + [3{\cdot}83098] \sin. l - [3{\cdot}83692] \cos. l, \cos. (L - 4^\circ\ 14'{\cdot}5)$$

The *Greenwich* mean time of beginning and ending of totality may be found from

$$\text{Cos } w = -17{\cdot}5228 - [1{\cdot}74616] \sin. l + [1{\cdot}68499] \cos. l, \cos. (L - 150^\circ\ 25'{\cdot}5)$$
$$t = 18\text{h. } 17\text{m. } 58{\cdot}5\text{s.} \mp [2{\cdot}09477] \sin. w + [3{\cdot}77348] \sin. l - [3{\cdot}84594] \cos. l, \cos. (L + 16^\circ\ 32''{\cdot}8).$$

"In the above formulæ L expresses the east longitude of the point from Greenwich, taken positive; l is its geocentric latitude, and the quantities within the square brackets are logarithms. Upper sign for beginning of totality, lower sign for ending.)

"It has been stated above that the eclipse of next April may probably be the most favourable for observation that can take place during the present century. In the eclipse of 1878, July 29, the duration of totality is shorter, and the same is the case in the eclipses of 1882, 1887, 1900, &c. In the eclipse of 1886, August 29, the only easily accessible and favourable station appears to be the Island of Grenada, in the West Indies, where the duration of total eclipse is 3m. 15s., commencing at 7h. 10m. A.M. local time, with the sun at an altitude of 20°; thence the course of the central line is over the North and South Atlantic Oceans, to a point on the African coast north of St. Philip de Benguela. In the eclipse of 1892, April 26, the central line appears to have a sea-track through nearly its whole extent, if indeed it touches land at any point, which requires a more precise computation than I have yet made to determine. The eclipse of 1893, April 16, is the only one that can compare favourably, as regards length of totality and track, with that of the present year: at a point in the vicinity of Ceara, in the Brazils, the duration of total eclipse is 4m. 44s. with the sun at an altitude of 76°."

We may conclude our article by stating that the observations for which the Council of the Royal Society have obtained a promise of a grant in aid amounting to 1,000*l.* will be limited to photographing the spectra of the chromosphere and coronal atmosphere.

For this purpose a siderostat has been placed at the disposal of the Royal Society, and another will be ready in time. These instruments have been made by Messrs. Cooke and Sons, of York, who have in some respects, with their usual skill, improved upon Foucault's model. As an instance of international courtesy which must not be unrecorded, we may state that M. Leverrier would have placed the original instrument devised by Foucault himself, and now at the Paris Observatory, at the disposal of the Royal Society, had it not been constructed solely for the latitude of Paris.

Besides siderostats, it is proposed that equatoreals shall be sent out also, provided with apparatus for spectrum photography, quartz prisms and lenses being generally employed.

The Secretary of State for India (Lord Salisbury), the Viceroy of India, and the Admiralty officials are all hearty in their co-operation. It is hoped that Col. Tennant and a strong staff of assistants will also be on the scene of action.

Although the time is short, then, we may fairly hope that good work will be done. Of this we may be assured, that whether the observers be many or few, whether the weather be good or bad—and General Strachey considers the chances all that can be wished for—the action of the Royal Society and of the Government will redound to the credit of English science, and a bright page may be added to the scientific annals of our time.

EDITOR

COUNT RUMFORD'S COMPLETE WORKS

The Complete Works of Count Rumford. (Published by the American Academy of Arts and Sciences.)

THE American Academy of Arts and Sciences is doing good service and teaching the Old World a sound practical lesson by undertaking the publication of such a work as this. The question of what form should be given to the monument of a great man is often discussed, and fairly admits of much debating; but when the benefactor of humanity whose memory is to be preserved is one who has done the high service of extending the boundaries of science, we may safely venture to affirm that whatever *other* monuments may be erected, the *first* should be a complete and carefully compiled record of all his researches. The demand for this arises from the manner in which the results of original scientific work are usually communicated to the world, *i.e.* in the form of papers read before learned societies or contributed to magazines, or published as pamphlets, and thus scattered far and wide and liable to be forgotten or even altogether lost. Such a publication should precede all other forms